# ACCLIMATIZATION TO LOWERED BAROMETRIC PRESSURE AS A MEANS OF INCREASING RESISTANCE TO VARIOUS EXTREME FACTORS

## (In Lieu of an Introduction)

The creation of methods which will permit expansion of the /5* boundaries of adaptation of the organism of animals and man to various adverse environmental factors and the scientific basis thereof is one of the most important problems encountered in modern biology and medicine. It is a problem that has attracted the attention not only of clinical physicians, biochemists, pharmacologists and physiologists concerned with work and athletics, but also of specialists working in the field of aviation and space medicine. These specialists are involved because of the possibility that in flights involving modern aircraft difficult stress situations may arise that would require the mobilization of all adaptation potentialities of the organism. In such case the success of the flight and, certainly safety in a number of instances, may be determined by the ability of the organism to adapt itself to various extreme factors: lowered barometric pressure, oxygen deficiency in the air inhaled, high G-loads, a significant elevation or lowering of the environmental temperature, etc. From the above, it becomes obvious that it is essential to establish scientific research to find means of raising the ability of an organism to adapt itself to different types of significant change in the environment.

Primarily there are two basic means of solving this problem that are possible: (a) using pharmacological compounds and various biologically active materials (vitamins, hormones, products of metabolism), which purposefully increase the adaptation potential of an organism, and (b) increasing the resistance of an organism by "acclimatization" of it to certain changes in the environment. This latter means is especially promisings since it promotes the /6 development of natural mechanisms of adaptation. However, the question does arise: for which of these factors involving change in the environment is it most feasible to promote adaptation? Experiments compiled in the field of athletic physiology, aviation and space medicine and mainly high-altitude physiology furnish a basis for assuming that training for oxygen deficiency is probably one of the most effective means of raising the adaptation potential of an organism. This opinion is based not only on the fact that oxygen starvation will lead to the development of non-specific functional stress, as several investigations have emphasized (Sel'ye, Lengli, Brüner and Klein) but also since oxygen deficiency

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* Numbers in the margin indicate pagination in the foreign text.

in itself is an essential element in the mechanism involved in many factors that are characteristic of flight and which act on an organism: increased gravity, high and low temperature, etc.

A great number of methods are known that will result in inducing a hypoxic state. Which of these should be selected for purposes of training? It is immediately apparent that there are two such methods which can be used to induce a "normal" physiological form of hypoxia. We are speaking here first of all about the intense muscular activity involved in various types of athletic exercise and secondly when an extended time is spent under conditions of a gaseous environment having a lowered partial oxygen pressure in the inhaled air which is the case at certain altitudes in mountains and is also encountered in high-altitude training in a pressure chamber and in the inhalation of gaseous mixtures which are poor in oxygen.

Training for the "physiological" form of hypoxia by raising the altitude in conjunction with muscular activity is apparently one of the most promising means of increasing the adaptation potential of an organism. Numerous physiologists have described the effectiveness of using this method for the most varied purposes (the training of pilots, athletes and for medical treatment of certain illnesses). Moreover, for almost 30 years now experiments have been periodically made on using adaptation to conditions of medium and high altitude both for the practical purposes of clinical medicine (Sirotinin et al) and for training of the healthy, including pilots (Sirotinin et al, Vladimirov et al, Hartmann et al). For this purpose several investigators have indicated the effectiveness of conducting systematic ascents in a pressure chamber (Strel'tsov, Vasilenko, Gazenko, Kuznetsov, Brüner and Klein).

At the present, several foreign specialists in the field of aviation and space medicine believe it to be feasible to include high-altitude training in the training schedule of astronauts. Apparently in this respect medical research abroad in recent years has been expanded, having been conducted in expeditions at various /7
altitudes, including research in specially organized high-altitude physiological laboratories. One such laboratory was even established in the Himalayas in the region of Mt. Everest at an altitude of 5800 m.

The basis of these developments is apparently the result of studies by Hurtado and Clark, Balk, and Velasquez et al. who showed that the Peruvian Indians who live at altitudes of 4000-4500 m, have exceptionally high physical endurance and resistance to acute hypoxia. Pressure-chamber studies, at altitudes of 9000 and 12,000 m, of reserve time (retention of the ability to function without oxygen) showed that in the Indians of Peru this time is significantly greater than in persons who are not adapted to high altitude. This furnishes a basis for assuming that the physiological picture of persons adapted to high altitude represents a

particular standard towards which we should tend in training.

Here it is only natural that the question should arise as to how high-altitude or pressure-chamber training should be carried out in order to produce results that are sufficiently effective. No scientific basis of a rational system of training for purposes of making a lengthy and maximally possible increase in the resistance of an organism to different extreme factors has been given to date. Study of this question, which is so important for practical application, is also one of the problems examined in the present research. However its successful solution will depend on studying the physiological mechanisms of an organism's adaptation to conditions of oxygen deficiency. Such an approach to the problem was solved by two basic means, based on which the investigations that were conducted in the period 1964 - 1966 were developed, both under conditions of high-altitude in the region of the Caucasus at altitudes of 2000 - 4200 - 5600 m, and in the laboratory in pressure chambers.

In experiments on animals several sides of the physiological mechanism of adaptation of an organism to lengthy stay under conditions of a rarefied atmosphere were primarily studied; in similar studies with humans, the effectiveness of the selected program of "acclimatization" was basically calculated.

Thus, investigations with humans had a practical purpose; here it was shown that people who have never lived in the mountains and who remain for a period of a month in mountains at altitudes from 2000 to 4200 m with sporadic ascents to altitudes of 5000 - 5600 m will have a pronounced increase in their resistance to acute hypoxia and to the influence of transversely directed accelerations. These data, which have been found at the present time only on a relatively small number of individuals, suggest the expectation that "acclimatization" under high-altitude conditions can be successfully used in a system of preparation and training of athletes, astronauts and members of other specialities which periodically require of man the ability to undergo extreme degrees of physical and intellectual/8 stress.

In making such investigations it would seem that we can never be satisfied only by determining the resistance of the examinee to various influences prior to and after high-altitude training, but it is essential that the dynamics of development of the adaptation syndrone be studied so as to find a fixed correlation between the proper adaptation improvements and the effects attained as a result of training.

The results of the study conducted with mountain climbers also confirm the feasibility of using high-altitude training. The high resistance to acute oxygen starvation and to the effect of G-loads, found in the majority of mountain climbers even before their next trip into the mountains, permits assuming that with a rationally

constructed program of "high-altitude" training, and probably pressure-chamber training as well, we can assume the attainment of a lengthy, at least for several months, retention of the increased resistance achieved in the process of training to adverse environmental conditions. The negative results obtained in studying the effect of high-altitude adaptation for the resistance of an organism to the influence of elevated environmental temperature will require further testing since there does exist a basis for assuming that under the temperature conditions of high-altitude adaptation, they can be avoided. It is essential, from the viewpoint of practical utilization of high-altitude training, that we consider the fact that the most distinct positive effect was found in persons who had relatively low resistance to the effect of extreme factors prior to the mountain-climbing expeditions. At the same time, persons remaining under high-altitude conditions and who possess a previously high resistance to the effect of G-loads and acute hypoxia, increased their resistance to the above factors relatively little. From the above discussions we can conclude that in preparing a flight crew, astronauts and probably athletes it makes sense to use high-altitude training mainly for those individuals whose previous resistance to the effect of extreme factors is low.

Analysis of the data revealed that a significant increase in respiration during acute hypoxia is characteristic of the majority of mountain climbers, with respect to which even at the present time considerable attention should be paid, in the process of adaptation to hypoxia, to respiration by trying to increase the effectiveness of this function to its maximum. This position corresponds fully to the results of investigations by Lauer, Kolchinskaya, Seredenko and others who found an increasing optimization of the exhalation function in persons who have shown a significant increase in their resistance to the effect of acute hypoxia and transversely directed accelerations after undergoing high-altitude training.

In conclusion, let us look briefly at the results of experiments directed toward studying the physiological mechanism of adaption to hypoxic hypoxia of animals. /9 The process of acclimatization to a lengthy period of time under conditions of a gaseous environment with lowered partial pressure of oxygen will apparently lead to an essential rebuilding of many of the control systems of an organism. There exist in the literature several discussions which differ from one another to a greater or lesser degree, that reflect the participation of functional systems of the organism in adaptation (Strel'tsov, Barcroft, Charniy, Gellhorn et al, Barbashova). Considerable significance is given by several authors in such case to changes in the functional state of the central nervous system and to the endocrine glands. Thus, an essential role is played by the adrenal and pituitary glands at various stages of adaptation, as noted by Sel'ye and Lengli. The question as to the significance of the nervous system in the development of adaptation to hypoxia has as yet been studied very little. Basically at the

present time only the significant role of the sympathetic nervous system has been mentioned (Barbashova). The significance of the cortex of the major hemispheres and the structure of the gray matter in the development of adaptation has as yet been studied only slightly.

We assume that adaptation to hypoxia, just as to many other influences, can be studied as a problem of memory. Such resistration (remembering a new situation) is carried out at various levels, in many cellular structures of an organism and obviously first of all in the control system. This latter is of interest to the authors of this collection in explaining the role of the endocrine glands and the nervous system in the development of adaptation.

In the papers published in this collection, experimental data are given which characterize the development of adaptation to lowered barometric pressure in animals who have had their most important control systems such as the adrenal glands, the pituitary glands, the cortex of the major hemispheres and the cerebellum operationally disconnected. The results of the investigations showed that after removing these systems it is possible to produce an adaptation development which has certain characteristics. Substantial data relative to the effectiveness of the various systems of acclimatization and the significance of the physical load in the process of adaptation to hypoxia were also obtained in experiments on animals.

Many investigators (Sirotinin, Armstrong et al) believe that the effectiveness of systematic pressure-chamber training is low and can not compare with residence under high-altitude conditions. The results of experiments on animals show that gradual adaptation is most effective in a pressure chamber when altitudes up to 7000 m are attained.

Thus, there exist sufficient theoretical premises for use in training in a pressure chamber, with respect to which at the present time it is opportune to pose the question of design and manufacture /10 of special large scale "acclimatization" pressure chambers in which it is possible for several persons to remain for a long period of time involving the wide utilization of different types of physical loads rather than under conditions of relative hypodynamia as in previous research.

The authors hope that the materials in this collection will be of aid to physicians, physiologists and biologists who are studying the problem of adaptation of animal and human organisms to hypoxia.

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